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AN APPROACH TO RISK ANALYSIS: A PROCESS VIEW

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ABSTRACT

From an academic perspective, risk analysis is a reasonably well defined process. The application of risk analysis to a real-world problem however, is a difficult task with few well-defined approaches. The practical application of risk analysis is hindered by the lack of an adequate framework with which to approach the problem. Without such a systematic approach, it is difficult to provide useful risk information to a decision maker.

The question of risk, and more fundamentally the uncertainties of future events, needs to be examined to identify the potential competitive and inherent risks associated with alternative military force postures. Having a basic understanding of these uncertainties and their consequences is most important in the decision process.

This paper is intended to aid analysts to understand and structure risk problems. It is not meant to be an academic exercise on the statistics of risk, but rather a practical "handbook" which may be used to view a risk problem as a sequence of steps in a process of problem solving.

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AN APPROACH TO RISK ANALYSIS

Evolution of the Project

The current Air Force Studies and Analyses (AF/SA) development project on risk-analysis methodology is based on traditional concepts of risk. The project tries to assess the degree of vulnerability of strategic forces to inherent and competitive risk factors. The focus is to explicitly identify elements of uncertainty in strategic decisionmaking, rather than to implicitly assume them away. Moreover, risk analysis (i) examines those uncertainties to isolate the most severe risk elements and (ii) predicts the consequences of force-structure alternatives.

The AF/SA risk-analysis project began during the Air Force consideration of alternate basing modes for the M-X deployment. The concern was that every mode had its share of uncertainties—and that it would be useful (i) if the elements of uncertainty for each could be identified and (ii) if the possible consequences could be evaluated. It was realized, early on, that conventional risk analysis could provide the framework, but, by itself, was not powerful enough to credibly address the many faceted problem.

In the evolution of this effort, the element of risk analysis that appeared to have the most merit was the concept of a process appropriate to risk determination. This process is one in which: (i) the risk elements are identified; (ii) their likelihood of occurrence is determined; and (iii) an evaluation of their impact is made. It provides a framework for continuous evaluation, whereby, as the environment changes, new factors are determined and the system sensitivities are reevaluated.

Current Preceptions of Risk Analysis

Generally, risk analysis has been employed by the Department of Defense (DOD) in the acquisition process as an aid to decisionmakers in their selection of weapon systems. Three major areas where risk analysis has been used in this process are cost, schedule, and performance. From a force-structure point of view, risk must be presented in the larger context of combat capability, rather than within the context of considerations that are generally given to risk in the acquisition cycle. Since we are talking about execution of a total force structure, risk must be viewed in the context of all of the components of the battlefield.

If analysis is used to provide information to decisionmakers, then how does risk analysis differ from what is already provided? Generally, a study will take on rigid assumptions and scenarios which will be reflected in the results. The results can be applied only for the stated assumptions and conditions. To provide more information, the analyst usually institutes a sensitivity analysis to allow variables to go beyond the range of the assumptions. Yet, we still are uncertain that everything will work as assumed—and that interactions that are possible and cannot be modeled will not unexpectedly occur. We cannot really predict how things work.

Risk analysis, on the other hand, begins by assuming that things will go wrong; and it is structured to provide information about how it occurs. The objective of risk analysis, then, is to provide the decisionmaker with information on the uncertainties that lead to failure.

What is Risk?

What is risk, and what are the elements of a risk problem? Risk, in its simplest terms, is exposure to the chance of loss. Risk analysis, then, can be described as a process by which uncertainties can be exposed through qualitative and quantitative methodology for the purpose of decisionmaking. The four elements of a generalized risk problem are (i) alternative weapon systems; (ii) measures of effectiveness (MOEs); (iii) a set of risk factors; and (iv) risk-assessment criteria.

a. Alternative Weapon Systems. This first element relates to the fact that total force structures or force-mix uncertainties may not always surface in a narrow study of alternative weapon systems. A subordinate or superordinate force-structure component may malfunction under unforeseen constraints and, in turn, cause the weapon system to operate in a suboptimium mode.

For example, either the weapon carrier or its communications interface may create uncertainty as to accomplishment of the mission. The power of risk analysis lies in the fact that it requires an analyst to:

- Structure a problem in terms of the force-structure components of a weapon system.
- Look for areas of uncertainty which could cause failure in the designed operational capability of the total weapon system.

b. Measures of Effectiveness. Measures of effectiveness are central to all analytical endeavors and are of prime importance in risk analysis. A tactical force-structure problem may use movement of the forward edge of the battlefield area as a measure of effectiveness. A strategic measure may be: (i) attrition of forces; (ii) force-reaction time; (iii) endurance of forces; or (iv) force-level statics (e.g. equivalent megatonnage) after a nuclear exchange.

Risk-assessing measures must be established to:

- Provide a means of ranking force-structure alternatives.
- Determine the most-to-least severe source of risk.

Overall, the MOEs must be capable of addressing risk created within all elements of the force structure.

c. The Set of Risk Factors. With regard to this third element of a risk problem, risk occurs in two ways in a force-structure problem. We labeled these, inherent and competitive risks. The first, inherent risk, is the risk created by uncertainties built into the force structure. An example is the circular error probability of a weapon system. It is often used to assess the capability of a strategic force structure when this is actually a statistical measure for an individual weapon system. It remains an area of uncertainty, especially when applied to an enemy force capability.

The other source of uncertainty is from external factors, which we call competitive risk. Risks are generated through Soviet actions to counter the effectiveness of US deployed systems. These actions may force us to operate the weapon system in an off-design mode and create uncertainties within the system.

An example of competitive risk was the Soviet use of SA-2 surface-to-air missiles to force B-52s designed for high-altitude penetration into a low-level mission profile. This in turn caused the wing life of the aircraft to be reduced because the aircraft experienced higher fatigue by training in this off-design mode as a low-level penetrator.

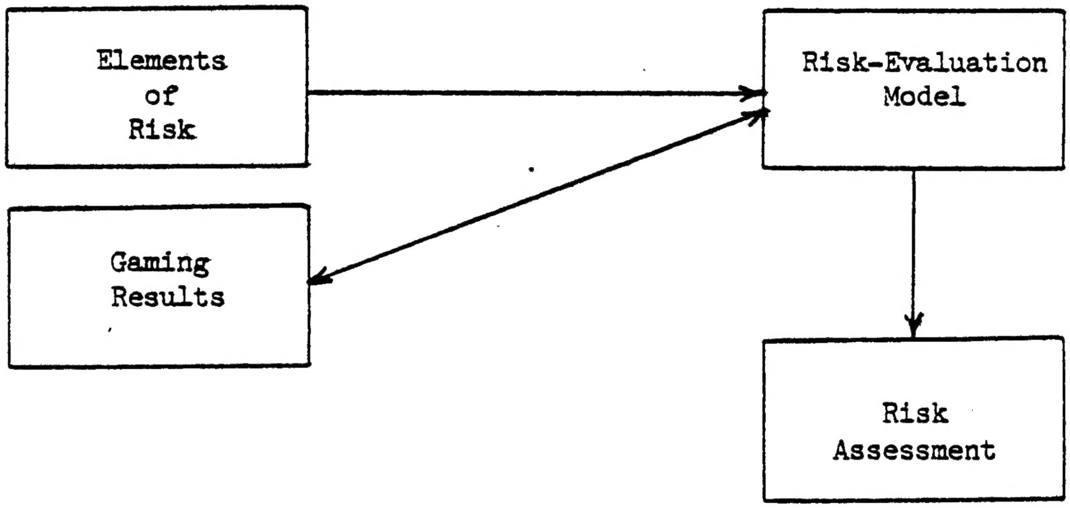
In the early phase of weapon-system development, trade-offs are constantly being made to reduce uncertainties of performance, reliability, and maintainability. What happens is that risks are traded intuitively between the inherent and competitive factors. The prime concern is that the force structure will operate reliably and effectively. Inherent and competitive uncertainties must be surfaced and examined throughout the development process, because we have (i) very limited experience employing current force structures in actual warfare and (ii) essentially no nuclear experience.

d. Risk-Assessment Criteria. They are the fourth element of a risk problem. Decisionmakers have preferences which must be understood by the analyst. These preferences become the basis for developing a risk-assessment criterion. The criterion, then, is a translation of these preferences which the analyst in turn uses to order alternatives and develop indifference functions between alternatives.

The Risk Process

Schematically, a traditional, force-structure risk assessment problem might look like this:

TRADITIONAL STRUCTURING OF A RISK PROBLEM



The Elements of Risk are the identified areas of uncertainty in the force structure; i.e., inherent or competitive uncertainties for each alternative. The Gaming Results interact with the Risk-Evaluation Model to evaluate the consequence of each risk factor for each alternative. The Risk-Assessment module then examines the consequence of each risk factor and orders them by risk criteria.

This structure assumes that the component interrelationships are well understood and can be modeled--which is not always the case. Often the models needed for risk evaluation don't exist, and the time available to answer a question is too short to develop them. Therefore, the following process is suggested as a means to approach a risk problem. (This is not to suggest that there is a simple way to solve any risk problem, because each problem has its own set of complexities.)

Ground Rules for Laying Out A Risk Problem

This is a description of a process for defining a problem and identifying all elements of it for a risk analysis. The first item of importance is to have a broad set of ground rules for gathering information and laying out the risk problem before proceding to the description of the steps in the process. (The appendix is a checklist for conducting a risk analysis. It summarizes the material in the following sections.)

a. State the Problem. There is a need to recognize that one cannot accurately predict the future. Therefore, the problem should be stated in a manner that encompasses a broad range of eventualities. Remember that the objective of a risk analysis of a force structure is to (i) assess uncertainties and (ii) evaluate the possible consequences of these uncertainties on outcomes, goals, and objectives.

Another output from risk analysis is:

- o Identification of key failure modes within the force structure.
- o Examination of possible off-design performance caused by outside influences.

The problem statement must also encompass, in scope, the interfaces that exist in an actual combat operation.

b. Establish Alternatives. The alternatives, generally, have been established by the decisionmaker, and there is little leeway for deviation. On the other hand, a possible source of alternatives is an investigation of changes to doctrine and policy. If time permits, there is no reason that these may not be addressed to add depth to the analysis and provide insight to the decisionmaker. Always be aware that the decisionmaker has preferences which will influence him in his selection.

c. Understand the Issues. The issues, by their nature, will focus on uncertainty. Issues develop because of the various points of view held by individuals and organizations. These usually are parochial to the organization supporting a specific viewpoint. Issues are interesting because they represent diverse views of policy, objectives, and doctrine.

d. Know the Environment. It's important to understand the operational environment of the system. The environment is that set of things outside of the weapon-system boundaries. It is an area where doctrine and tactics are supreme, and each will have some different uncertainties associated with it.

e. Know the Components of the System. A force structure has many components, with many interfaces. It can be thought of as a network, with the relationships represented by the arcs, and functional components represented by the nodes. To perform a risk problem, it is necessary to understand the characteristics and objectives of each of the nodes and their relationship to one another.

Steps in the Risk Process

A process is best described as a sequence of connected steps to achieve a goal. The goal is to provide the decisionmaker with information about the uncertainties that abound in his planning problem. The role of the risk analyst is to identify potential failure events and assess the outcomes of those events.

The first step in the process is to determine what event (or combination of events) produce uncertainty in the force structure's capability to attain its objectives. This involves examining technology, environment, threat, weapon-system characteristics, and issues to identify possible outcomes which--based on these conditions--lead to failure. Although this is an exhaustive approach for the analyst, there will be benefits gained by reviewing these factors synergistically.

The second step is the most difficult, because it is the evaluation of the consequences of the outcomes. That is, the outcomes must now be evaluated in terms of the force structure's ability to achieve objectives. The MOEs used are important because they must address all of the outcomes. If an MOE can't be developed to do this, then outcomes will not be comparable in the next step: the risk assessment. So the MOE is critical, because it must be a representative measure of force-structure capability. It will also provide a means to translate uncertainty into trade-off options during the selection of alternate weapon systems.

The final step is the risk assessment. There has been little mention of expectation and likelihood in this paper. The reason is that we are working with an ill-defined problem. It has considerable complexity, and doesn't adapt well to popular methodologies. Up to this point, the problem shouldn't have many boundaries in answering the question of risk. Instead, the assessment step should be a place where objective people provide their experienced judgment on what is likely or highly unlikely to occur.

Criteria for judgment should be based on economic and political factors, as well as military experience. Risk analysis deals with future events and uncertainties. So, eliminating the below-the-threshold consequences early on by being too structured restricts visions of the future possibilities. We have all been surprised by events that didn't seem possible in the not-too-distant past. Technology is moving at such a rate that surprises may become more frequent and more disturbing.

Summary

Risk is a subject that is often discussed in connection with military decisionmaking, whether it be (i) an option in a crisis or (ii) deployment of a new weapon system. All of us have an intuitive understanding of what risk means. But it's another thing to quantify it and to convince a decisionmaker that it's an important consideration.

Risk is a "squishy" problem that doesn't lend itself to modern mathematical models except in simple situations. It is better approached with probability distribution based on estimates by professionals. Even in the acquisition process (where risks of schedule, cost, and performance are treated), it's largely a matter of polling professional judgment. Without a concerted effort to employ a systematic approach and win the acceptance of professional judgment as a valued assessment, risk analysis will be nothing more than an incomprehensible oddity.

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APPENDIX

RISK-ANALYSIS CHECKLIST

Risk analysis is a process for exposing uncertainty by employing qualitative and quantitative methodology for the purpose of decisionmaking. It is a difficult task because it is an exhaustive iterative approach which often must rely on subjective judgments for evaluation. But, as long as decisions of consequence affecting the future are made, there will be a concomitant need for more information about the consequences of those decisions. This checklist is provided as an aid to analysts who are about to perform a risk analysis.

1. Statement of the Problem. To structure a risk problem one must be keenly aware of the decisionmakers objective. Secondly, the statement of the problem must embody that objective and must be broad enough in scope so as not to limit the study to a particular alternative or preclude others by definition.

A risk analysis must take the systems approach to problem-solving. By being exhaustive, a risk analysis will probe all possible sources of uncertainty. This requires searching into the associated logistics, communications, strategies, and all other elements that comprise the total system.

- State the problem in a concise manner.

2. Identify the Alternatives. Alternatives are the means by which the objective can be obtained. Alternatives may consist of hardware, policy, or strategy changes, and need not be obvious substitutes for one another. New alternatives may be discovered as a result of a broad review of the objective and should be listed among the alternatives.

- List the alternatives (i.e., systems, policies, etc.).

3. Determination of the Risk Factors. The purpose of this section is to identify the uncertainties for each alternative. There will be uncertainties resulting from (i) hardware design; (ii) strategies and tactics; and (iii) the evolving nature of the threat.

- One purpose of risk analysis is to expose the ways each alternative can fail. Identify key failure modes of each alternative critical to keeping it mission-capable.

- Of the failure modes identified, list those that are attributable to inherent factors; i.e., design features of the system.

- Of the failure modes identified, list those that are caused by changes in tactics, technologies, or combat doctrine of the threat. This is the competitive risk.

4. Evaluate the Risks. The purpose of the evaluation section is to assess the effects of each of the uncertainties identified in the previous section by alternative. The evaluation may be carried out by using quantitative methods, or it may be based on estimates made by specialists in the field. The latter approach would probably be a subjective evaluation where the specialist would judge the risk and define what the evaluation meant in terms of degradation to the system. The point here is that the measure of degradation, whether it be determined by using a deterministic model or a subjective evaluation by a technical specialist, has to apply to all of the risks. They must all be measured on a common scale to permit relative ranking of alternatives by risk.

5. Risk-Analysis Profile. Here, the purpose is to report the results of risk-analysis evaluation and display the relative ranking of alternatives by severity of risk. Secondly, it is to identify what specific kind of risk is associated with each alternative; i.e., inherent or competitive.

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